

## PATENT SPECIFICATION

1,170,965

DRAWINGS ATTACHED.

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International Classification:—G 06 k 1/12.

## COMPLETE SPECIFICATION.

## Information Recorded with Coded Ink.

We, AMERICAN CYANAMID COMPANY, a corporation organized and existing under the laws of the State of Maine, United States of America, of Berdan Avenue, Township of Wayne, State of New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus and a system for retrieving information recorded in the form of a coded ink symbol. The invention also relates to an information carrier for use with such apparatus or in such a system. In applicant's co-pending application 10198/66 (Serial Number 1,143,362), there is described a process for encoding and retrieving information by means of so called coded inks, that is to say, inks which have various combinations of components which fluoresce under ultraviolet or other short wave illumination at different wavelengths. Preferably there are used for at least some of the components chelated lanthanide ions which under ultraviolet light of suitable wavelength fluoresce in very narrow bands, because the chelated ions are excited by the ultraviolet to a particular metastable state, and in falling back to a lower energy level emit fluorescent radiation of a narrow wavelength band depending on the particular lanthanide ion. Coding is preferably by the presence or absence of the particular components, and this permits a number of symbols equal to  $2^n - 1$ , where  $n$  is the number of components. For example, four components permit 15 different symbols, which is sufficient to use the inks for encoding all ten digits for the encoding and decoding of

numbers. The process of the above referred to application has the great advantage that the different symbols depend in no way on the shape of the symbol, which can be a dot, rectangle, or any other shape, and does not require to be in the shape of particular digits. As a result, the accuracy of the coding and retrieval of information is in no way adversely affected by change in the shape of coded symbols. For example, in a typical case, where the code is for a number on bank checks, if the bank check is carelessly torn off or the shape of one or more digits is altered, this in no way affects the accuracy of readout of coded inks.

The number of different symbols possible depends on the number of distinct photoluminescent components which are available. The number is somewhat limited by the number of lanthanide ions which can be made into chelates economically. There is described in the application referred to the use of more than one level of compound, for instance two levels as well as absence, which increases considerably the number of symbols possible but only at a price of reduced signal to noise ratio, that is the desired identification over spurious signals produced becomes less sure.

In a first aspect of the present invention there is provided apparatus for retrieving information recorded in the form of a coded ink symbol on a carrier, the ink of at least a first portion of the symbol containing at least one of a group of photoluminescent materials capable of fluorescing at different predetermined wavelengths upon illumination by radiation at a wave length shorter than that of visible light, and the ink of at least a second portion of the symbol having

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a color with reflecting characteristics for the colors red, green and blue such as to reflect, upon illumination with white light, none, all, one or two of said colours, the apparatus comprising first means for illuminating such a symbol or said first portion thereof with short wavelength radiation; second means for illuminating said symbol or said second portion thereof with white light; a plurality of detectors responsive to different ones of said predetermined wavelengths and located to receive fluorescence from said symbol or said first portion thereof upon illumination as aforesaid, and responsive to different ones of said colors and located to receive reflections thereof from said symbol or said second portion thereof upon illumination as aforesaid; and means coupled to said detectors to provide a signal indicative of the information recorded in the coded ink of said symbol.

In a second aspect of the present invention there is provided a system for retrieving information recorded in the form of a coded ink symbol comprising a carrier, an ink symbol on the carrier, the ink of at least a first portion of the symbol containing at least one of a group of photoluminescent materials capable of fluorescing at different predetermined wavelengths upon illumination by radiation at a wavelength shorter than that of visible light, and the ink of at least a second portion of the symbol having a color with reflecting characteristics for the colors red, green and blue such as to reflect, upon illumination with white light, none, all, one or two of said colors; first means for illuminating said symbol or said first portion thereof with short wavelength radiation; second means for illuminating said symbol or said second portion thereof with white light; a plurality of detectors responsive to different ones of said predetermined wavelengths and located to receive fluorescence from said symbol or said first portion thereof upon illumination as aforesaid, and responsive to different ones of said colors and located to receive reflections thereof from said symbol or second portion thereof upon illumination as aforesaid; and means coupled to said detectors to provide a signal indicative of the information recorded in the coded ink of said symbol.

In a third aspect of the present invention there is provided a carrier bearing a coded ink symbol at least a part of the area of which includes more than one photoluminescent material capable of fluorescing under ultraviolet illumination and at least one substance having reflecting characteristics for the colors red, green and blue as to reflect, under white light illumination, none, all, one or two of said colors.

The detection of a fluorescence wavelength or a color with the apparatus or system above defined is preferably for the presence or

absence of the wavelength or color, but the detection can be for different levels of response.

In embodiments of the present invention components which have color in the visible spectrum are combined with the photoluminescent materials. This permits multiplying the number of symbols possible with any given number of fluorescent components by a factor of at least seven, and under certain conditions eight. At the same time, all of the advantages of coded ink encoding and information retrieval are retained except for a minor disadvantage in certain situations. The preferred photoluminescent materials (described hereinafter) are essentially colorless, and therefore when they are the only components used in a coded ink system, the presence of the symbols may be secret. In other words, the presence of photoluminescent inks does not appear from an examination under visible light but only when illuminated with ultraviolet light or other suitable short wave radiation, depending on the nature of the fluorescent material. In the majority of uses of coded inks, it is unobjectionable if under observation by visible light it becomes apparent that there is some symbol present; and for many uses this may be desirable.

Various aspects of the practical application of the present invention will first be discussed in somewhat general terms. Let it be assumed that the four photoluminescent components are available for coded ink purposes. As is pointed out above, this permits fifteen different symbols. Now, by using three visible light detectors, for example red, green and blue, illumination by white visual light permits recording of additional information. A black pigment or colour will reflect no red, green or blue. A white color will indicate the presence of all three. A red color would indicate the presence of red, a green color of green, and a blue color of blue, whereas a yellow color would show the presence of both red and green, and a purple color the presence of both blue and red. In each case the appropriate detectors receive these signals: none of the three in the case of black, all three in the case of white, and the particular ones in the case of the colors. This adds to seven possibilities under visual light, which can be combined with each of the symbols shown by photoluminescent material, thus multiplying the number of symbols possible by seven. In other words, instead of fifteen symbols there would be 105. Theoretically it is also possible to have a cyan color, which would reflect both blue and green, and in such a case there would be eight possibilities with the three visible light sensors, and the number of symbols would be 120. With larger numbers of photoluminescent materials still greater numbers of

symbols are possible, for example with ten photoluminescent components either 7161 or 8184 respectively.

As has been pointed out above multiple level detection may be employed and the invention can be practiced with multiple concentration photoluminescent material.

It does not appear practical at the present time to illuminate the same symbol or a portion thereof simultaneously with both ultraviolet and visible light, because of the possibility of overlapping response from the different radiation detectors. This requires some means of separation; one solution can be a timing or time sequencing device in which the symbol is first illuminated with visible light and then with ultraviolet light with suitable synchronized timed connection to the radiation detectors associated with each type of illumination. This is a simple method, as synchronously sequential response circuits for the electrical output of the radiation detectors are standard items in electronics. Another method is to separate the symbol spatially into two portions so that one portion of the symbol containing the visible light components only is illuminated by visible light and a second portion of the symbol containing photoluminescent components only is illuminated by ultraviolet light. It is not essential that the symbol be in two separated portions, although this gives the greatest reliability. The symbol may be a single entity examined in different portions as regards color and ultraviolet fluorescence because none of the visible component colors intended to be sensed by the red, green and blue sensors reflect any of these colors when illuminated by ultraviolet light and the white light illumination does not cause fluorescence.

The use of time sequencing or space separation are two typical methods of preventing spurious response, but the invention is not limited thereto in its broadest aspects.

The invention will be described in greater detail in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagrammatic representation of an embodiment using space separated; and

Fig. 2 is a diagrammatic representation of an embodiment using time sequencing.

For simplicity the drawings will be described in conjunction with a system using four photoluminescent components and detectors therefor labelled A, B, C and D and seven visible components, black, blue, green, red, yellow, purple and white together with three sensors or detectors for red, green and blue respectively, which are labelled R, G, and B1. It is not believed necessary to describe the particular design of the radiation detectors, which may be provided with filters passing the desired narrow wavelength bands or dispersing means for the two types of detectors, such as prisms which separate the

different wavelength bands spatially. Such practice is within the compass of those skilled in the art.

In Fig. 1 there is a substrate or table (1) over which an information carrier, which may be a card, bank check or other surface on which the coded symbols are applied, is moved intermittently so that the two portions of a symbol (4a) and (4b), the former containing only photoluminescent components and the latter only visible components, are moved to successive positions where the symbol is under a sharp dividing baffle (5) defining first and second areas at which the portions (4a) and 4b are received. A visible light lamp (6) and an ultraviolet source, such as for example a mercury arc lamp with suitable filter (7), simultaneously illuminate the respective portions of the symbol through periodically operating shutters (8) and (9). When the symbol is positioned as shown in the drawing, the shutters are opened and the portion (4a) is continuously illuminated with the ultraviolet light, for example the 3130 Å mercury line, and the white visible light from the lamp (6) illuminates (4b). The ultraviolet light causes any photoluminescent components to fluoresce if they are present and each is detected by its own detector A, B, C, and D. Similarly, the seven visible color components in the portion of the symbol (4b) reflect and energize one or more of the detectors R, G, and B1 or none in the case of black. The detectors are shown as receiving light, reflected in the case of the visible and fluorescent in the case of the lanthanide ion chelates, through glass fiber optics tubes (11) of standard design, the bundle of glass fibers being protected with an opaque external cover, as is customary in such glass fiber light pipes. The detectors themselves use photomultiplier tubes of conventional design with suitable filters, for example interference filters, of the appropriate narrow band widths for the particular radiation to be received. As the photomultipliers and filters are of conventional design, they are not shown in detail but purely diagrammatically.

The signals from the various detectors are led into an electronic readout device (10), which can be of conventional design. The connecting wires are not numbered and are merely a diagrammatic illustration of electrical connection between the detectors and the readout. The readout, preferably, is also provided with suitable circuits for actuating the shutters (8) and (9). The lights (6) and (7) being of conventional design are shown without their feed wires in order to simplify the drawing. The readout device (10) gives a response depending on which of the detectors are energized and may have a window (12) on which the information conveyed by the coded ink of each particular symbol may

appear by conventional readout designs. The use of shutters is a simple form of inhibiting signals while the card (2) is moving from the recognition position of one symbol to that of another. This is only one illustration; the same effect can be obtained by cutting off or blanking the signals from the detectors in the circuits of the readout (10). The use of shutters, however, is a convenient and simple method of preventing unwanted signals during movement of the card (2) and, for many purposes, is preferred.

The information carrier, which will be described as a card for simplicity, is moved intermittently, the shutters (8) and (9) being closed during movement, to a position locating the next symbol under the baffle (5). Movement also, as is customary with digital readout, clears the readout (10) so that it is ready to respond to the next symbol. The shutters open, the symbol is irradiated with visible and ultraviolet light as described above, and the second digit or component part of the message transmitted by the symbols is then read out.

Fig. 1 shows symbols which are broken up into two separate areas, one having only visible components, the other only photoluminescent components. This gives the sharpest and most clear-cut separation. However, it is possible for the symbol to have all of the components in it together but of sufficient width or other dimension so that part of it is on one side of the baffle (5) and part on the other.

Fig. 2 illustrates the use of a time sequencing form of the invention, the same elements bearing the same reference numerals as in Fig. 1. In this case the substrate, that is, the moving card (2), carries only a single symbol (3). Light from the two lights (6) and (7) is alternately flashed onto the symbol by the rotating shutter disc (13) which is provided with an aperture (14). This disc turns on a shaft (15) rotated by a motor, (not shown). The shaft also contains a commutator (16) which sends pulse commands to the read-out circuit (10) which has to read out after the receipt of the necessary signals both from the detectors A, B, C, and D and R, G, and B1. The shutters (8) and (9) can be eliminated if desired, and movement of the card (2) can either be continuous or intermittent, for example during a portion of the rotation of the disc (13) when neither light goes through. As all of the operations except the mechanical movement of the card (2) are extremely fast, very high speed reading is possible, at least as high as in Fig. 1 where the mechanical movements of the shutters (8) and (9) as well as the intermittent movement of the card (2) set certain limits on practical reading speed. The rotating shutter (13) can be readily designed to operate at considerably higher speeds.

In Fig. 2 the lights (6) and (7) can also be actuated intermittently instead of using a rotating shutter, and of course in synchronism with the switching of the particular circuits to the radiation detectors. The elimination of another moving mechanical part is offset by the additional wear and tear on the lights, and the particular means for producing sequential illumination may be chosen in accordance with all of the factors of a particular operation, thus adding a desirable practical flexibility.

The description of the drawings shows the operation of various modifications of the present invention without describing specific photoluminescent materials A, B, C, and D. The invention is of course not limited either to the number of photoluminescent components or to their exact chemical nature. A typical example of four photoluminescent components is represented by A being 4,5-diphenylimidazolone-2. Components B, C and D can be chelates of europium, terbium and samarium respectively. Radiation detector A is sensitive to blue light, which is the fluorescence of 4,5-diphenylimidazolone-2 when activated by the 3130 Å line of the mercury vapor light (7). This same wavelength is also effective in causing the three lanthanide ion chelates to fluoresce. There is a further advantage over some other ordinary fluorescent material that there is a minimum confusion with optical brighteners often put in paper and other materials which only fluoresce significantly under longer wave ultraviolet, such as the 3650 Å line of the mercury lamp.

In the example given the fluorescence of the europium is in the deep red and of terbium in the green, while of course the diphenylimidazolone fluoresces in the blue. Since these colours are suitable also for the red, green and blue detectors for visible light operation, it is possible to use the same detectors for both purposes, thus requiring only four detectors instead of a total of seven. No problem is encountered with the narrow band fluorescence of the europium and terbium chelates, and the same narrow cutting interference filters may be used. There is plenty of energy available as the reflection of pigments or dyes taken with the quite strong visible light lamp permits adequate signal levels. Saving in the number of detectors is offset, but only slightly, by the necessity of providing some additional switching circuits in the readout (10), because obviously a particular detector, say the red detector, must be switched into different circuits when it is responding to fluorescence under ultraviolet light than when it is responding to visible light. These circuits, however, are simple, conventional, and thoroughly reliable, especially when modern solid state electronics are utilized, and so

for many purposes the saving in the number of detectors is distinctly worthwhile.

It should be noted that while the fluorescence from the lanthanide ion chelates is extremely narrow band and sharp, the selective reflectance of colours is often less sharp; for example many good red pigments reflect a little in the blue. This however, presents no problem because, as has been pointed out above, there is a great deal of radiation energy available in irradiating with visible light, and so when signals are coming from the visible light detectors the response of the readout system can be reduced in sensitivity sufficiently so that the small amount of reflectance outside of the range of the particular detector does not actuate the readout. Such level setting involves the most elementary of electronics and presents no problem at all. In the case where fluorescent detectors for europium, terbium and diphenylimidazolone are used also for the three visible light detectors, when illumination is by visible light and the signals from the detectors are switched to the visible light circuits of the readout (10), these circuits should of course be provided with the necessary attenuation or level setting, because in the fluorescence detection the amount of energy is considerably less, and therefore, ordinarily there should be no attenuation of signals coming from the detectors when they are detecting fluorescence.

It is an advantage that there is no critical level setting required so long as the levels are set in a range such that reflection outside the particular detector's band does not actuate the readout. The actuation occurs with any signals above a preset minimum, and therefore differences in efficiency of reflection of different pigments or dyes do not present any problem, because the readout of course responds to signals which indicate that a particular component is either present or absent, and so the high signal to noise ratio which is characteristic of this digital type of response is fully retained. Reference has been made above to the desirability for certain uses, such as for example bank check account numbers, of being able to read symbols by visible light without using ultraviolet light or combined ultraviolet and visible light. In the embodiments above described each symbol or at least a portion thereof is colored and hence, if shaped, is directly readable. The fact that the present invention can be practiced with shaped symbols which are visibly readable as well as readable from the code of the ink adds a desirable additional flexibility. It is an advantage of the embodiments described that more code possibilities can be achieved without sacrificing any of the code possibilities available with the simpler systems.

#### WHAT WE CLAIM IS:—

1. Apparatus for retrieving information recorded in the form of a coded ink symbol on a carrier, the ink of at least a first portion of the symbol containing at least one of a group of photoluminescent materials capable of fluorescing at different predetermined wavelengths upon illumination by radiation at a wave length shorter than that of visible light, and the ink of at least a second portion of the symbol having a color with reflecting characteristics for the colors red, green and blue such as to reflect, upon illumination with white light, none, all, one or two or said colors, the apparatus comprising first means for illuminating such a symbol or said first portion thereof with short wavelength radiation; second means for illuminating said symbol or said second portion thereof with white light; a plurality of detectors responsive to different ones of said predetermined wavelengths and located to receive fluorescence from said symbol or said first portion thereof upon illumination as aforesaid, and responsive to different ones of said colors and located to receive reflections thereof from said symbol or said second portion thereof upon illumination as aforesaid; and means coupled to said detectors to provide a signal indicative of the information recorded in the coded ink of said symbol.
2. A system for retrieving information recorded in the form of a coded ink symbol comprising a carrier, an ink symbol on the carrier, the ink of at least a first portion of the symbol containing at least one of a group of photoluminescent materials capable of fluorescing at different predetermined wavelengths upon illumination by radiation at a wavelength shorter than that of visible light, and the ink of at least a second portion of the symbol having a color with reflecting characteristics for the colors red, green and blue such as to reflect, upon illumination with white light, none, all, one or two of said colors; first means for illuminating said symbol or said first portion thereof with short wavelength radiation; second means for illuminating said symbol or said second portion thereof with white light; a plurality of detectors responsive to different ones of said predetermined wavelengths and located to receive fluorescence from said symbol or said first portion thereof upon illumination as aforesaid, and responsive to different ones of said colors and located to receive reflections thereof from said symbol or second portion thereof upon illumination as aforesaid; and means coupled to said detectors to provide a signal indicative of the information recorded in the coded ink of said symbol.
3. Apparatus according to Claim 1 or a system according to Claim 2, comprising means for controlling said first and second illuminating means to sequentially illuminate

said symbol or the respective portions thereof.

4. Apparatus or a system according to Claim 3 wherein one of said detectors is used for detection of fluorescence at a predetermined wavelength and reflection of one of said colors; and further comprising means operable in synchronism with said control means to separate the responses of said one detector to illumination of said symbol or the respective portions thereof by said first and second illuminating means.

5. Apparatus or a system according to Claim 3 wherein there are at least three predetermined wavelengths which are detectable by the detectors responsive to said colors, and further comprising means operable in synchronism with said control means to separate the responses of each of said color responsive detectors to illumination of said symbol or the respective portions thereof by said first and second illuminating means.

6. Apparatus or a system according to Claim 5 wherein the response band of the detector for the color green includes the fluorescence band of a terbium chelate and the response band of the detector for the color red includes the fluorescence band of a europium chelate.

7. Apparatus according to Claim 1 or a system according to Claim 2 wherein said first and second illuminating means are arranged to illuminate first and second areas at which said first and second portions of a symbol are received, said detectors being divided into first and second sets examining said first and second areas respectively.

8. Apparatus or a system according to

Claim 7 comprising means for intermittently moving a carrier to bring the first and second portions of a succession of symbols borne by the carrier to said first and second areas for examination.

9. A system according to Claim 2 wherein said photoluminescent material is a chelate of a lanthanide ion.

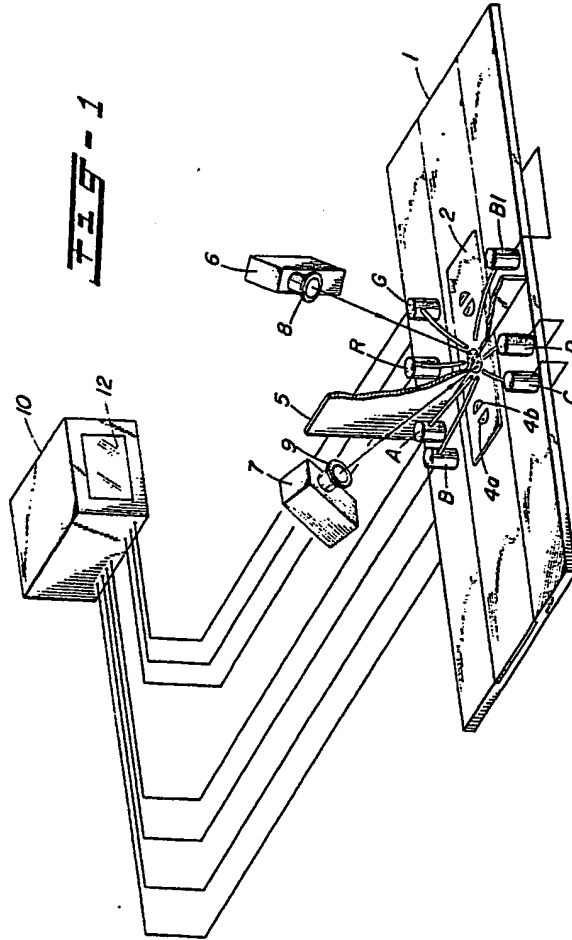
10. A carrier bearing a coded ink symbol at least a part of the area of which includes more than one photoluminescent material capable of fluorescing under ultraviolet illumination and at least one substance having reflecting characteristics for the colors red, green and blue as to reflect, under white light illumination, none, all, one or two of said colors.

11. Apparatus for retrieving information recorded in the form of a coded ink symbol on a carrier, substantially as hereinbefore described with reference to Figure 1 or Figure 2 of the accompanying drawings.

12. A system for retrieving information recorded in the form of a coded ink symbol, substantially as hereinbefore described with reference to Figure 1 or Figure 2 of the accompanying drawings.

13. An information carrier bearing a coded ink symbol substantially as hereinbefore described with reference to Figure 1 or Figure 2 of the accompanying drawings.

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## COMPLETE SPECIFICATION

**2 SHEETS**

***This drawing is a reproduction of  
the Original on a reduced scale***

Sheet 2

